

Arsenic Occurrence and Co-occurrence, Implications for Adsorptive Media Treatment

Phil Brandhuber¹

Nicole Graziano²

¹HDR Engineering

²McGuire Environmental Consultants



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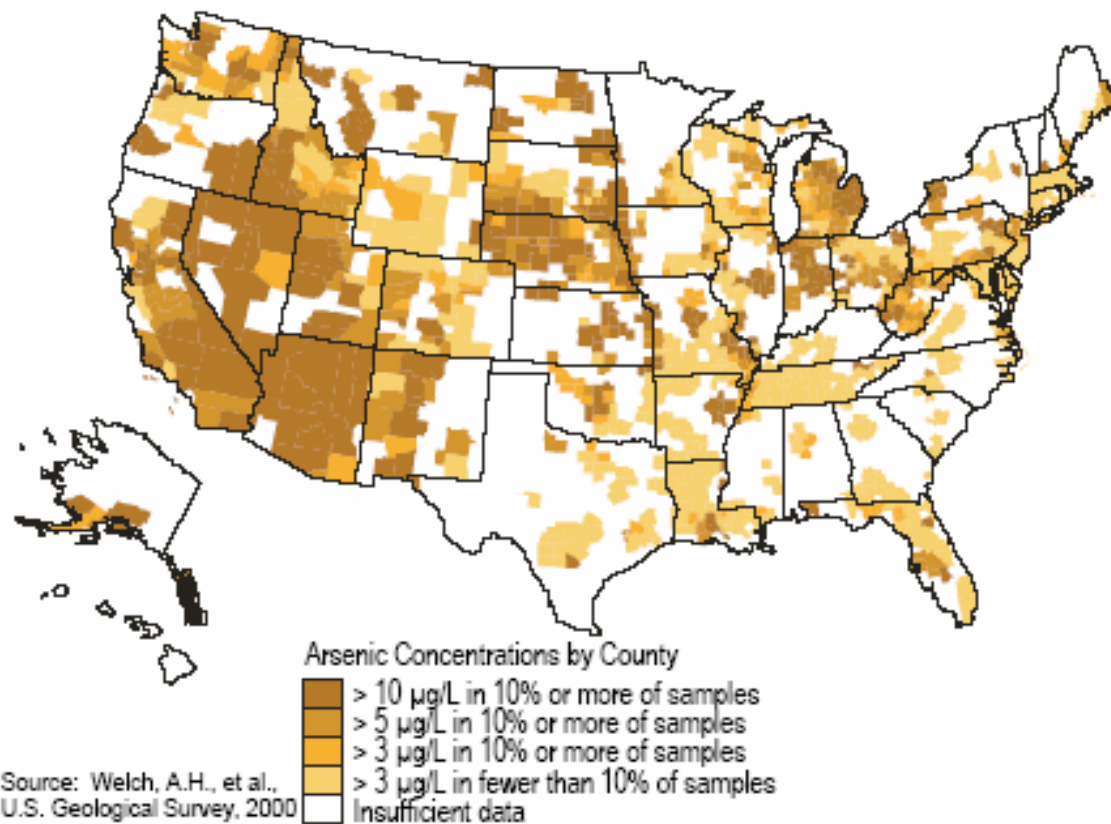
What is Occurrence and Co-occurrence? Why do we Care?

- Arsenic occurrence
 - How much arsenic is present and where
- Arsenic co-occurrence
 - What other contaminants are present in waters containing arsenic
- Adsorptive media treatment performance sensitive to water quality

What do we Know About Arsenic Occurrence and Co-occurrence?

- Arsenic occurrence
 - AWWA, National Arsenic Occurrence Survey (Frey et.al)
 - USGS, Arsenic Occurrence Analysis (Welsh et.al)
- Contaminant co-occurrence
 - EPA, Co-occurrence of Drinking Water Contaminants (SAIC)

Arsenic Occurrence – USGS Study



Objectives of AwwaRF Occurrence and Co-occurrence Analysis

- Part of AwwaRF Project 2731
 - Evaluate arsenic occurrence on a geophysical basis
 - Understand range of concentrations of water quality parameters which co-occur with arsenic
 - Provide guidance on conditions to evaluate performance of adsorptive media

Features of Analysis

- Retrospective
 - use existing USGS NWIS data
- Limited to groundwater
- Geographically dispersed and geologically varied
- Focused on waters suitable for consumption with appropriate treatment
- Contained in a data base

Data Base Development

Step 1

Extract suitable NWIS groundwater records for arsenic and co-occurring parameters



Step 2

Eliminate duplicate records and purge stations which are not of drinking water quality



Step 3

Treat records recorded as non-detect (ND)

- Eliminate ND's whose detection levels (DL) are too high to be meaningful
- Eliminate ND's recorded as 0 or where DL's are unreasonably low
- For use in statistical analysis, estimate values of remaining ND's at $0.5 \times DL$



Step 4

Create "Groundwater Arsenic Co-occurrence Database"

Criteria for Inclusion in Data Base

USGS	AwwaRF
Arsenic analytical method	Reported detection limit
Filtered arsenic	Unfiltered arsenic
Single analysis at site	Mean value at site
<ul style="list-style-type: none">• Exclude sites (arsenic)<ul style="list-style-type: none">– > 50°C– TDS > 2000 mg/L	<ul style="list-style-type: none">• Exclude sites (arsenic)<ul style="list-style-type: none">– Failed arsenic QC– Unacceptable co-occurring contaminant water quality– Geologic event sampling

Data Acceptance Criteria

Parameter	Unit	Acceptable Data		Acceptable Detection Limit
		Minimum	Maximum	
Alkalinity	mg/L	2	1000	-
Arsenic	ug/L	0.5	150	≤ 10
Calcium	mg/L	0.5	500	≤ 1
Chloride	mg/L	0.5	500	≤ 10
Fluoride	mg/L	0.1	10	≤ 0.1
Iron (dissolved)	ug/L	5	8000	≤ 10
Iron (total)	ug/L	5	8000	≤ 10
Potassium	mg/L	0.5	50	≤ 1
Magnesium	mg/L	0.1	100	≤ 0.1
Manganese (dissolved)	ug/L	1	1500	≤ 10
Manganese (total)	ug/L	2	1500	≤ 10
Sodium	mg/L	0.3	500	≤ 10



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Data Acceptance Criteria

Parameter	Unit	Acceptable Data		Acceptable Detection Limit
		Minimum	Maximum	
Nitrate	mg/L	0.1	50	≤ 1
pH	-	0	14	-
Phosphate (total)	ug/L	0.1	500	≤ 0.1
Selenium	ug/L	.5	200	≤ 10
Silica	mg/L	0.1	150	≤ 0.1
Sulfate	mg/L	2	500	≤ 10
TDS	mg/L	10	1500	-
Temperature	°C	0	50	-
Total Hardness	mg/L	10	1000	-
Well Depth	feet	N/A	N/A	-
Chromium (total)	ug/L	1	500	≤ 10

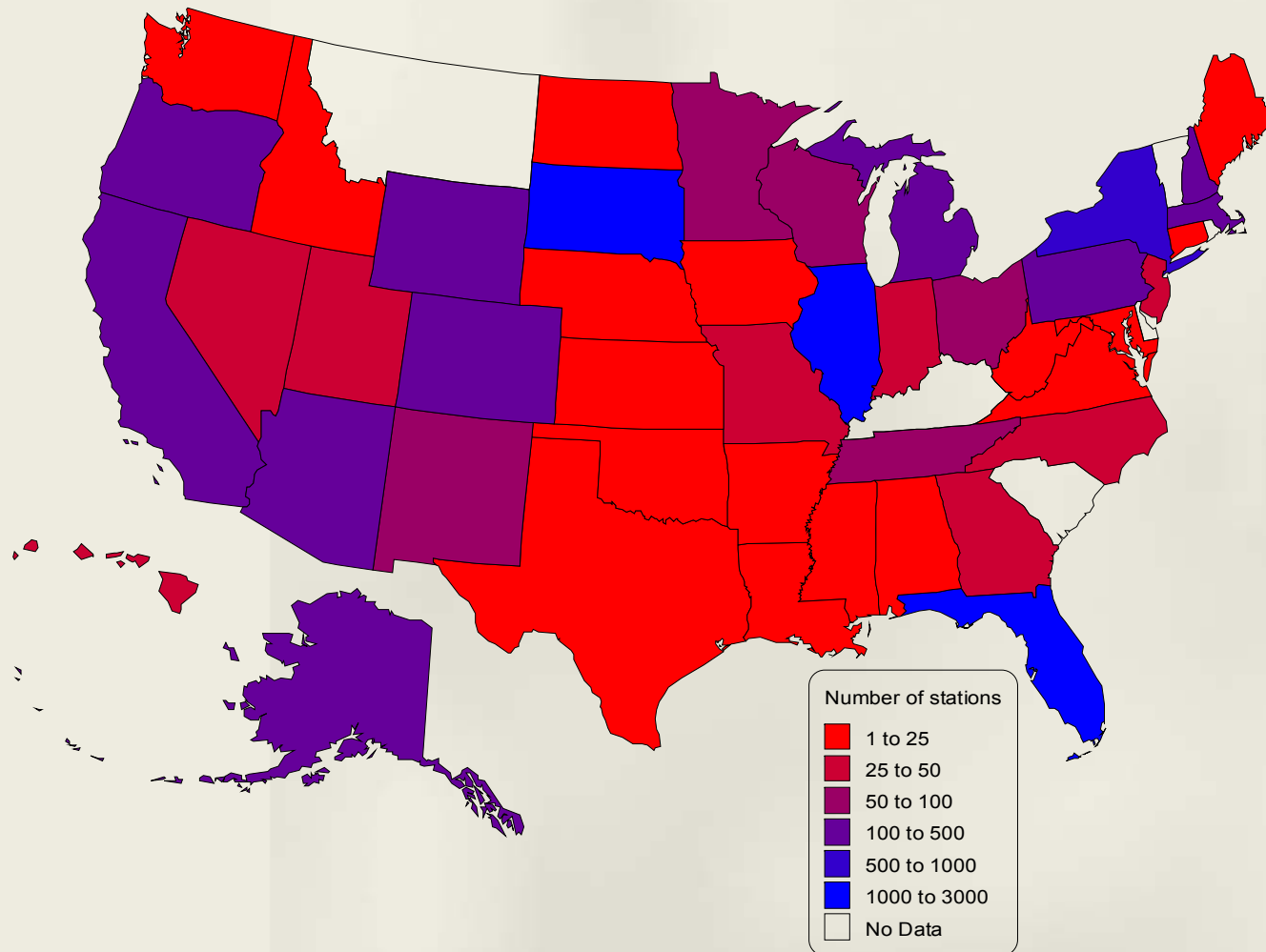


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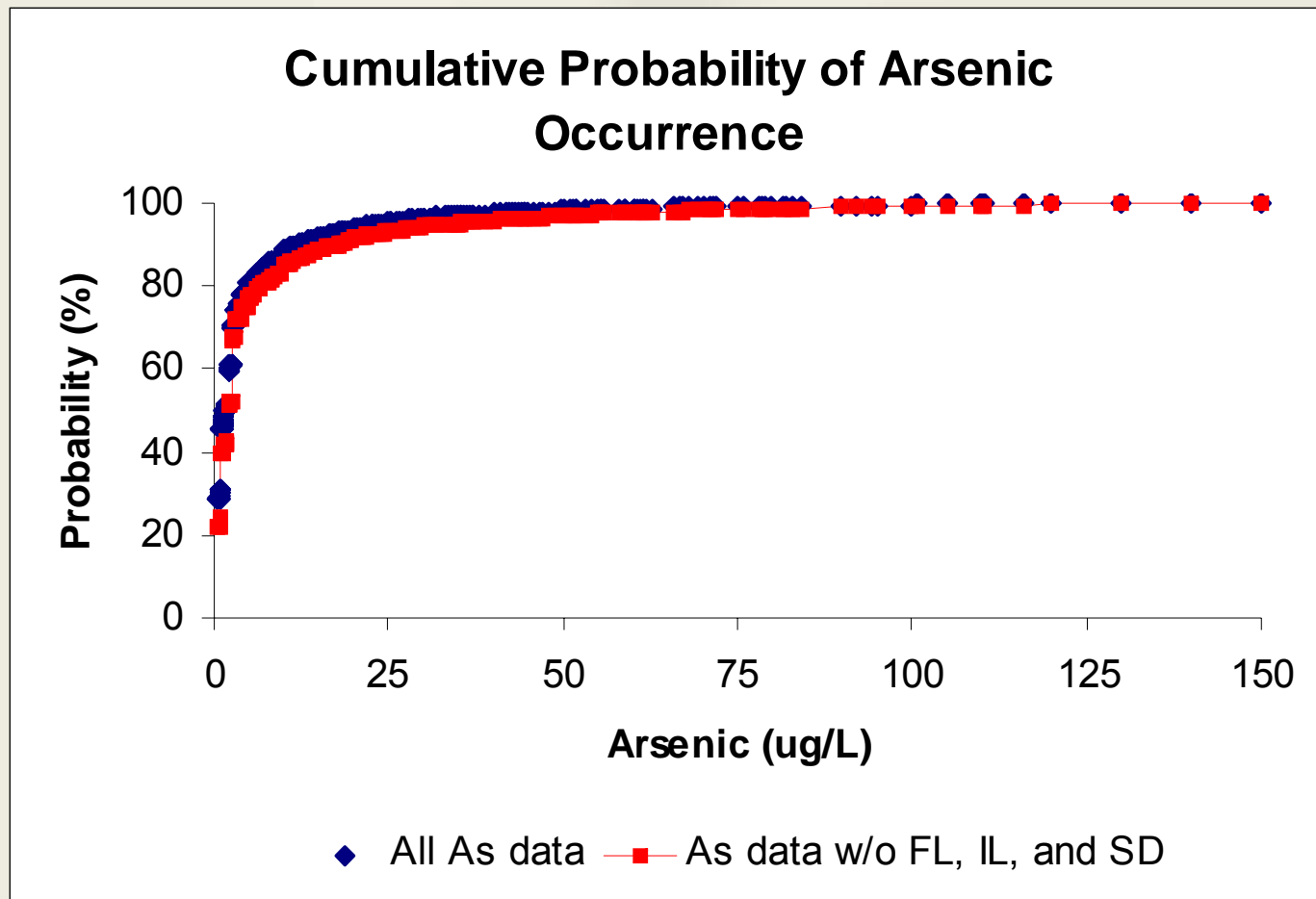
AwwaRF Groundwater Arsenic Co-occurrence Database

- Robust database of groundwater arsenic occurrence and co-occurrence
 - 9867 total sites
 - 8414 sites; mean As < 5 ug/L
 - 963 sites; mean $5 \text{ ug/L} \leq \text{As} < 20 \text{ ug/L}$
 - 490 sites; mean As $\geq 20 \text{ ug/L}$
 - 8546 sites with co-occurrence data
- 44 of 50 states represented in database

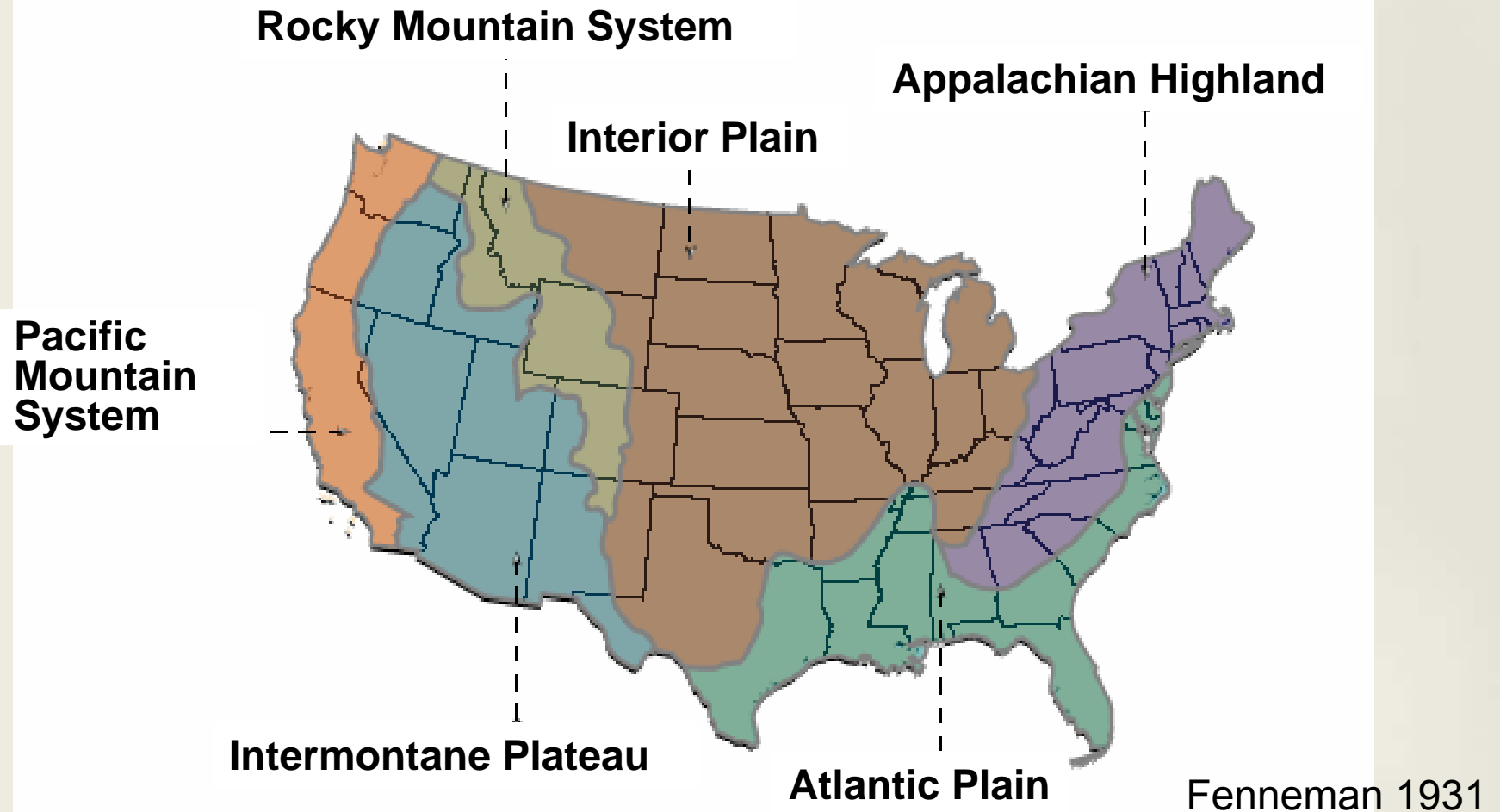
Number of Sites in Database by State



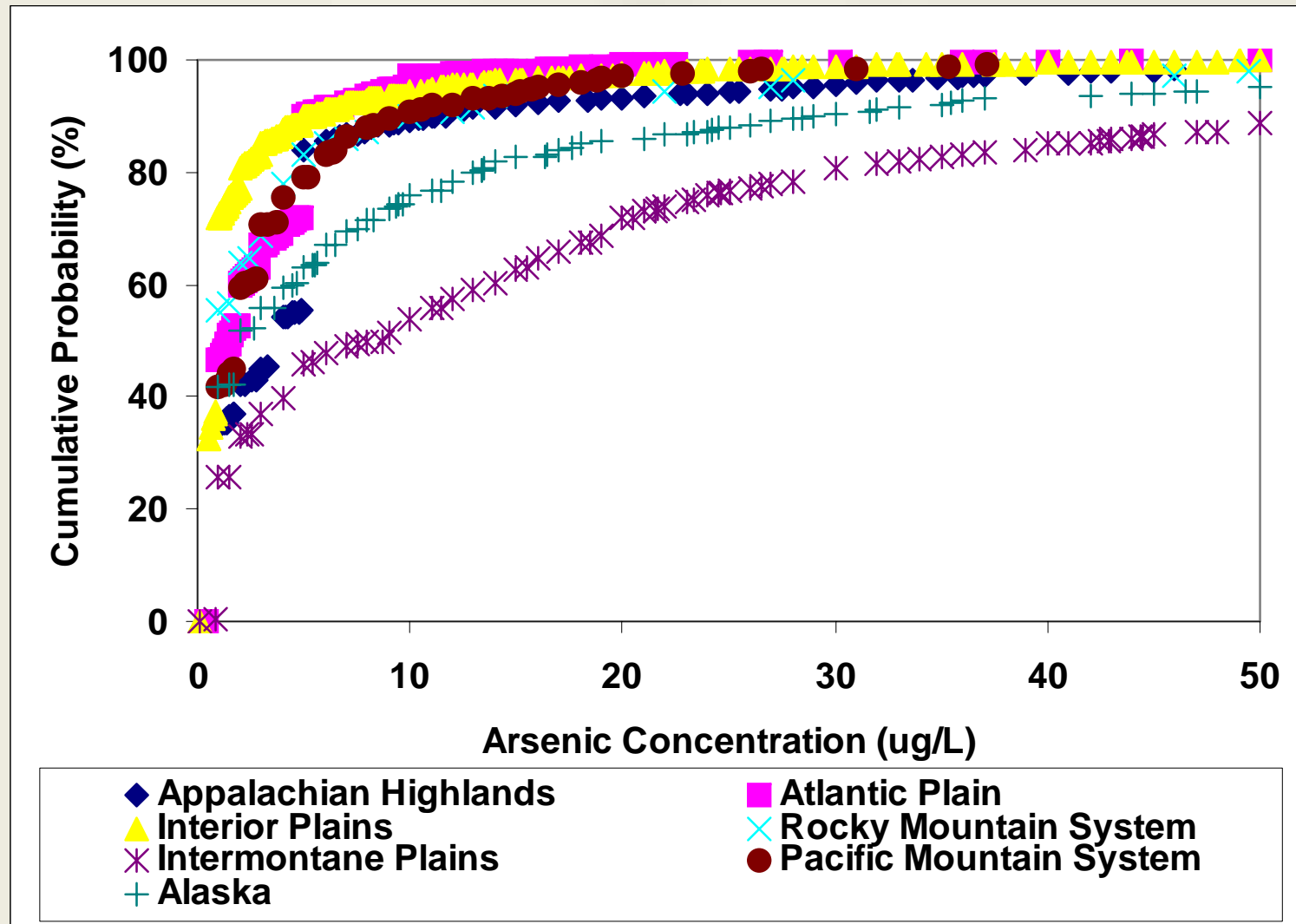
Cumulative Probability Distribution of Arsenic in Groundwater - all Sites



Physiographic Regions of the US



Arsenic Occurrence by Physiographic Region



Comparison of AwwaRF and USGS Analysis

Arsenic concentration in ug/L

Region	USGS			AwwaRF		
	Sites	Mean	Median	Sites	Mean	Median
Appalachian	2212	3	1	701	6	4
Atlantic	2047	2	1	2155	3	1
Interior	3947	5	1	5505	3	1
Rocky Mt	1028	7	1	108	6	1
Intermontane	4640	15	3	591	18	9
Pacific	2401	9	2	343	5	2
Alaska	-	-	-	418	11	2
Hawaii	-	-	-	46	-	-
Total	16275			9867		



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Binning of Arsenic Occurrence

Bin	Range	Description
1	$\text{As} < 5 \text{ ug/L}$	Low Arsenic
2	$5 \text{ ug/L} \leq \text{As} < 20 \text{ ug/L}$	Moderate Arsenic
3	$\text{As} \geq 20 \text{ ug/L}$	High Arsenic

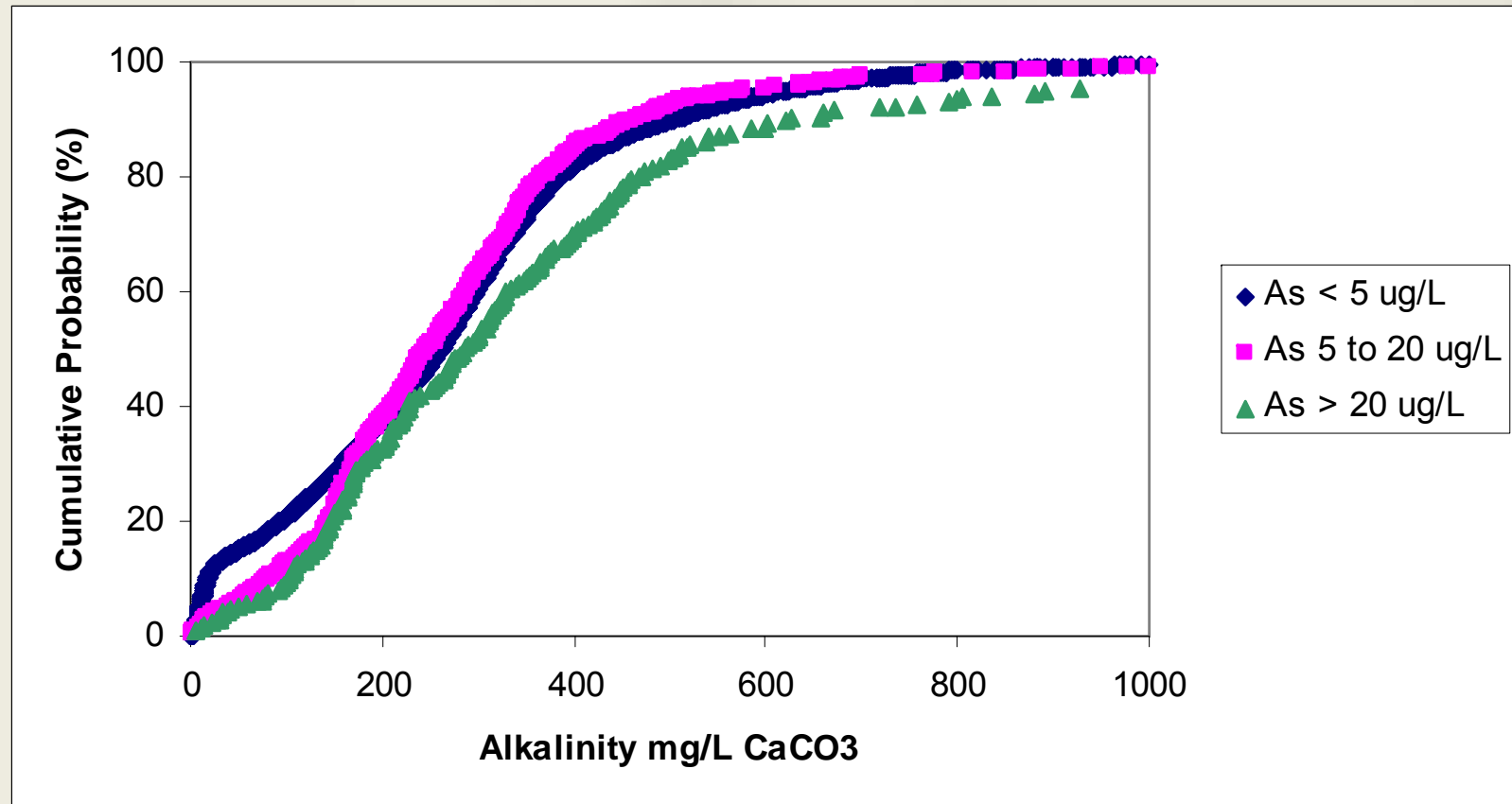
50th Percentile Concentration of Co-occurring Parameters

Parameter	Unit	Arsenic Bin			Trend
		Low As	Moderate As	High As	
Alkalinity	mg/L CaCO ₃	262	246	286	↑
Calcium	mg/L	53	55	43	↓
Chloride	mg/L	20	31	33	↑
Fluoride	mg/L	0.2	0.3	0.5	↑
Hardness	mg/L CaCO ₃	140	204	197	↑
Iron (dissolved)	ug/L	80	385	120	↑
Iron (total)	ug/L	99	1656	2016	↑
Magnesium	mg/L	13	12	18	↑
Manganese (dissolved)	ug/L	20	30	30	↑

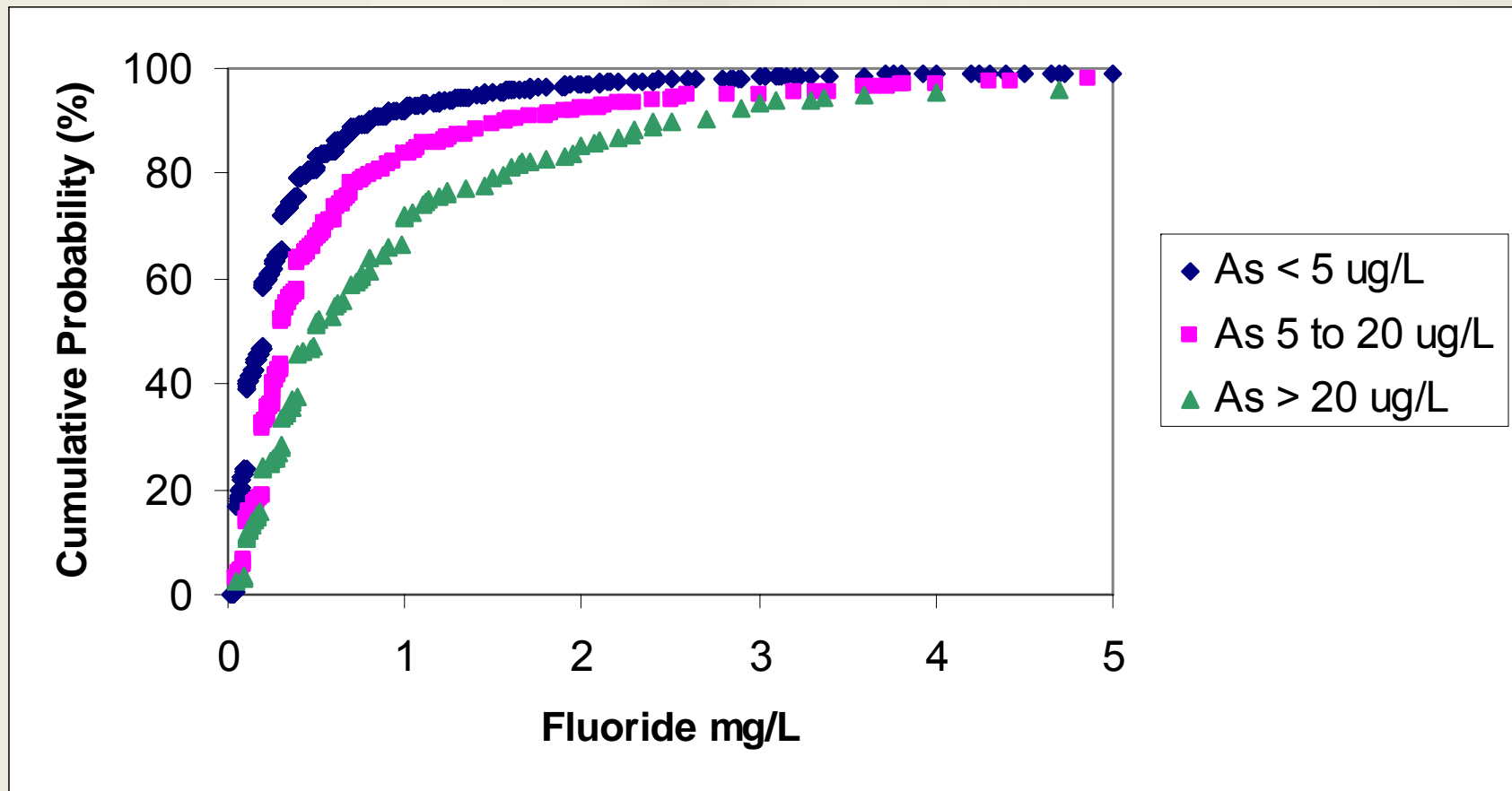
50th Percentile Concentration of Co-occurring Parameters

Parameter	Unit	Arsenic Bin			Trend
		Low As	Moderate As	High As	
Manganese (total)	ug/L	17	44	45	↑
pH	-	7.3	7.7	7.8	↑
Phosphate	mg/L P	0.05	0.13	0.34	↑
Potassium	mg/L	2	2.5	4	↑
Silica	mg/L SiO ₂	10	14	18	↑
Sodium	mg/L	30	43	87	↑
Sulfate	mg/L	22	27	31	↑
TDS	mg/L	374	389	436	↑
Temperature	° C	13.5	14	14	↔

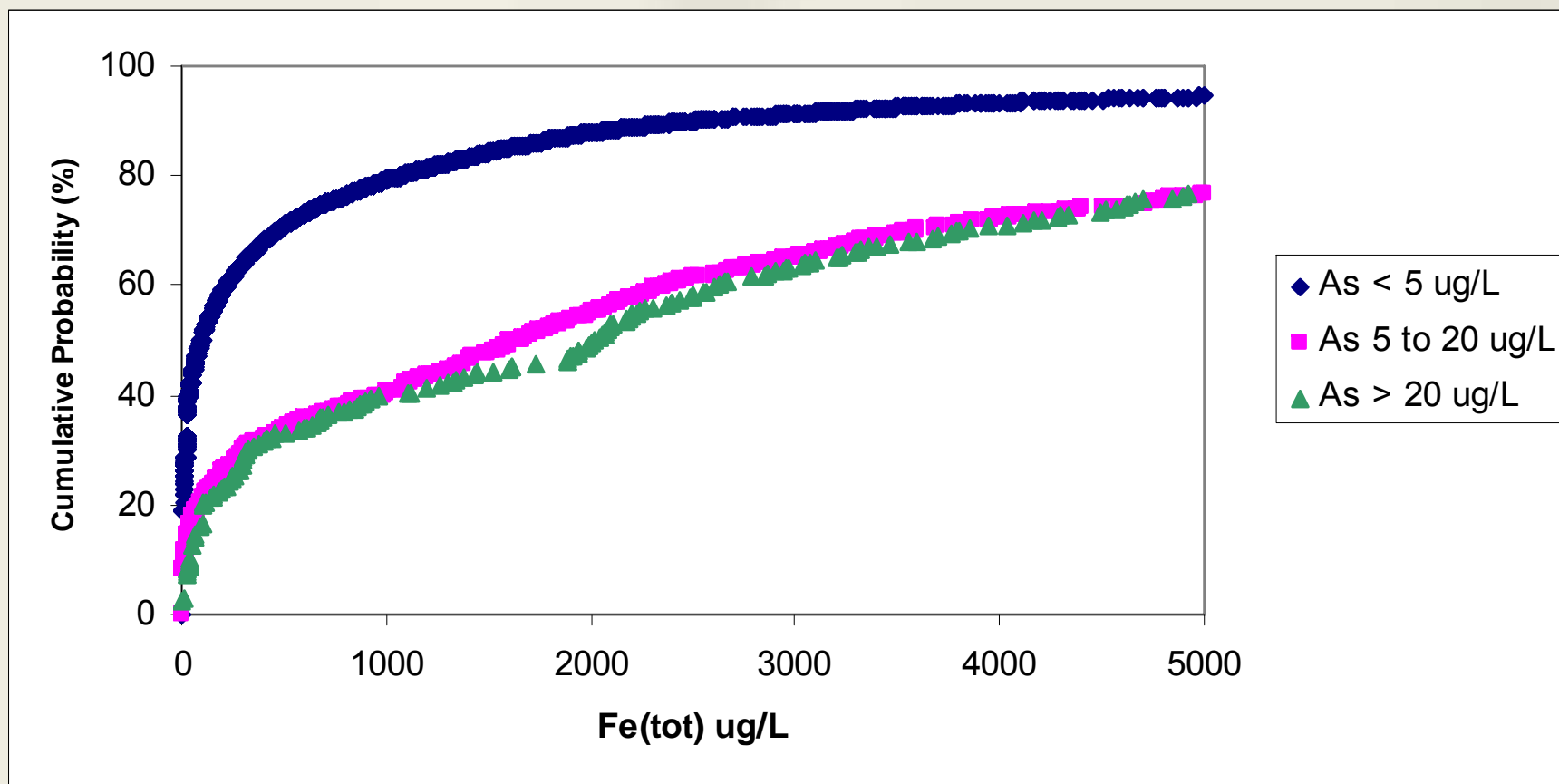
Cumulative Probability Distribution of Alkalinity by Binned Arsenic Concentration



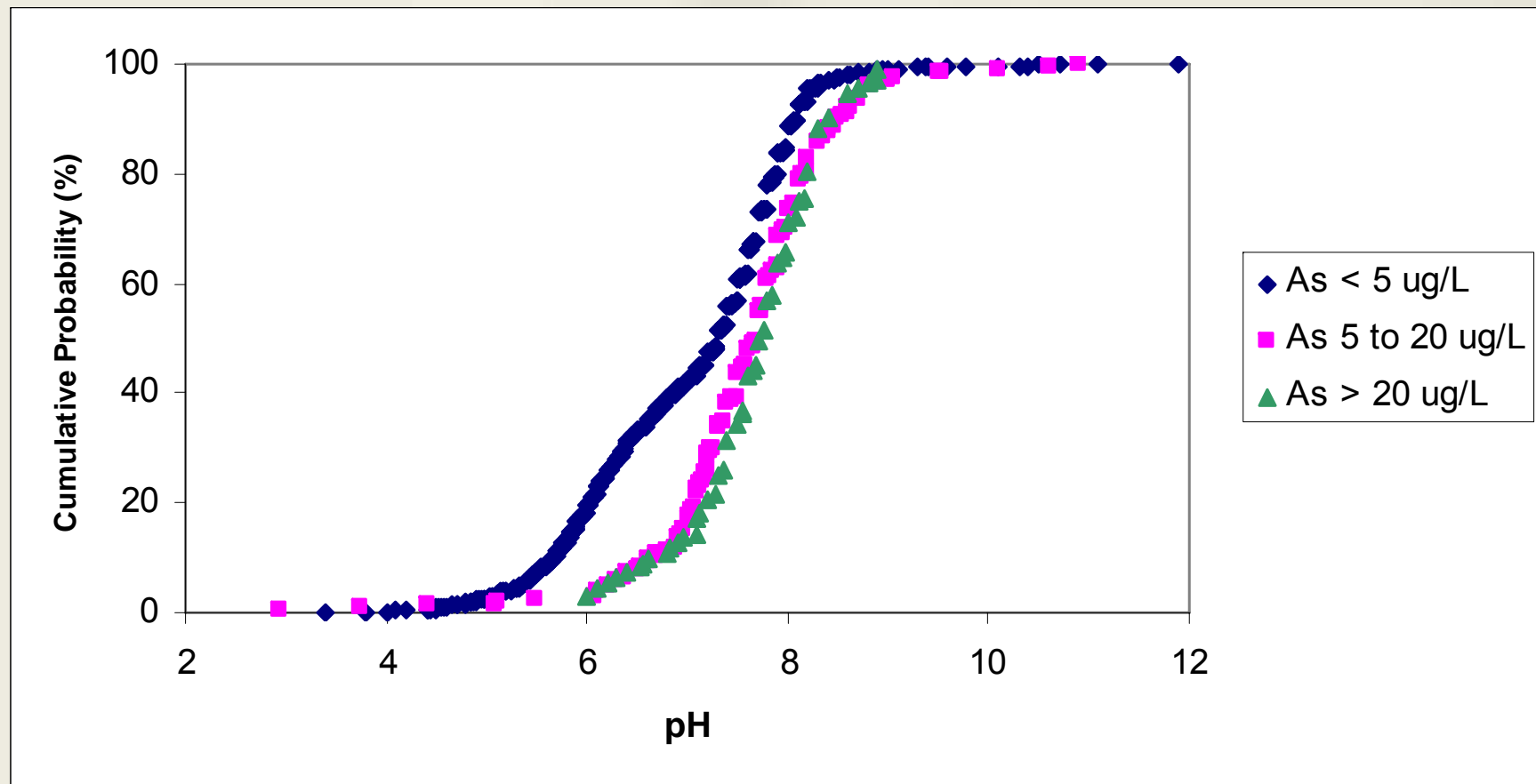
Cumulative Probability Distribution of Fluoride by Binned Arsenic Concentration



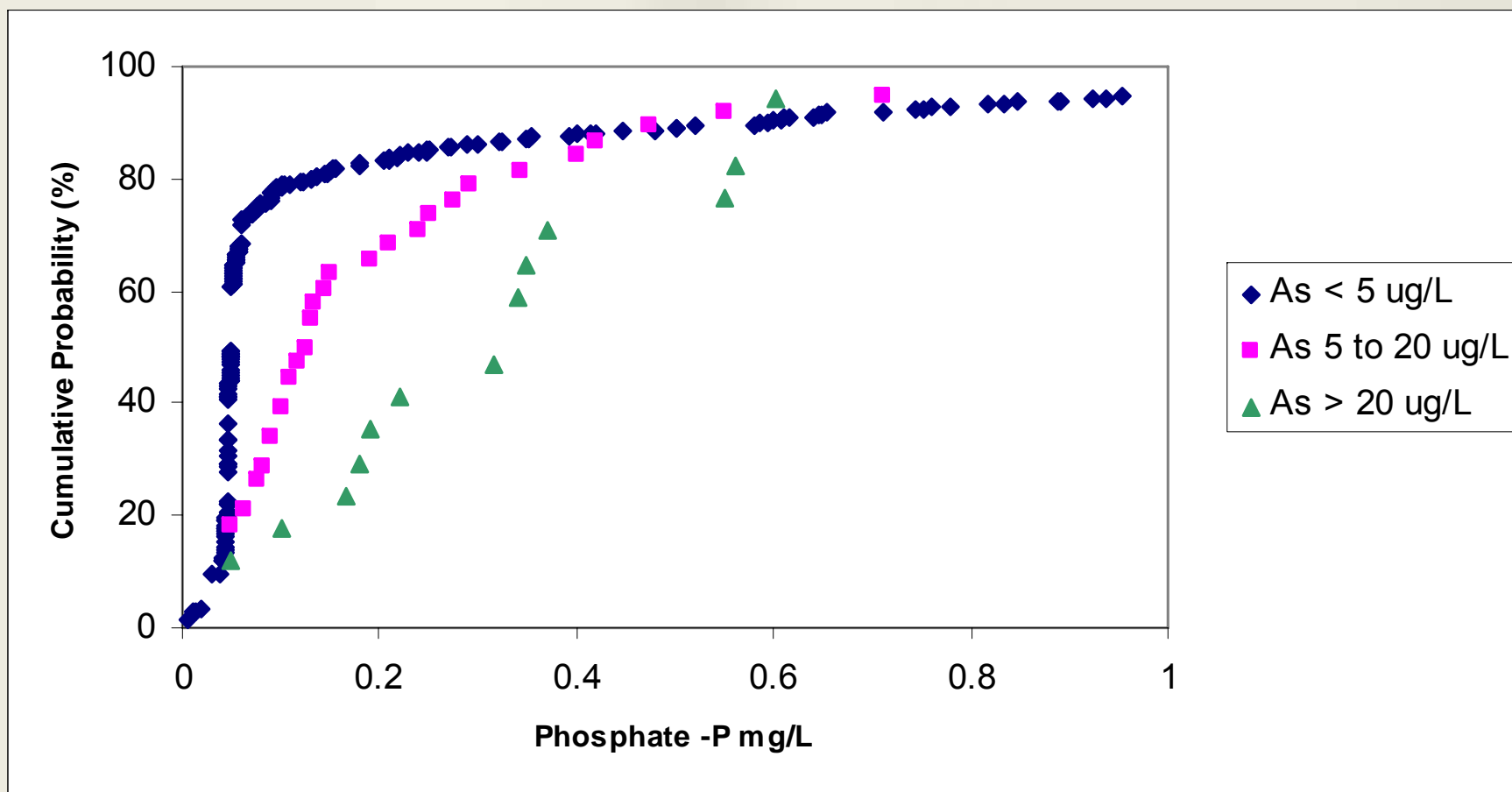
Cumulative Probability Distribution of Iron(total) by Binned Arsenic Concentration



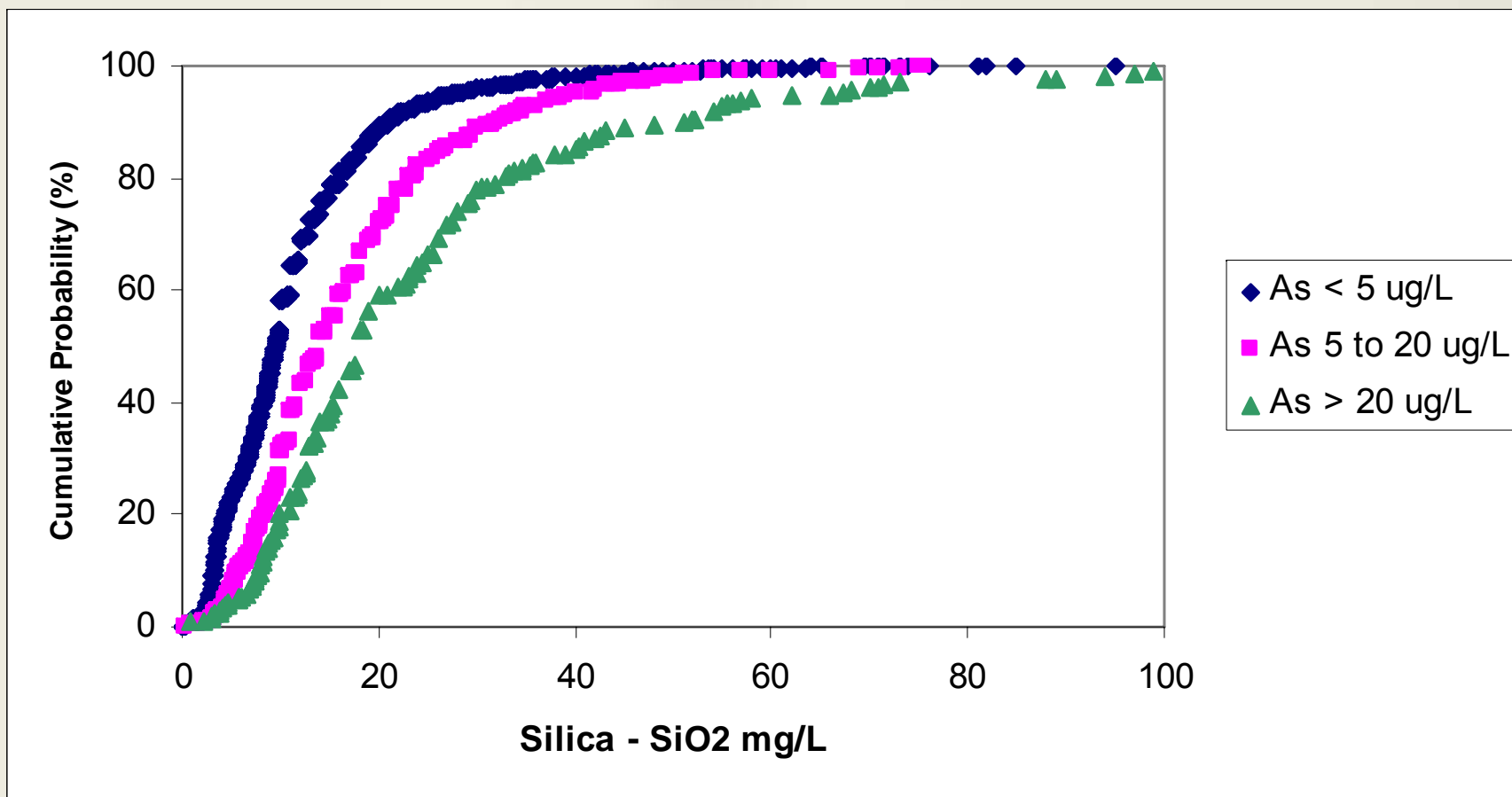
Cumulative Probability Distribution of pH by Binned Arsenic Concentration



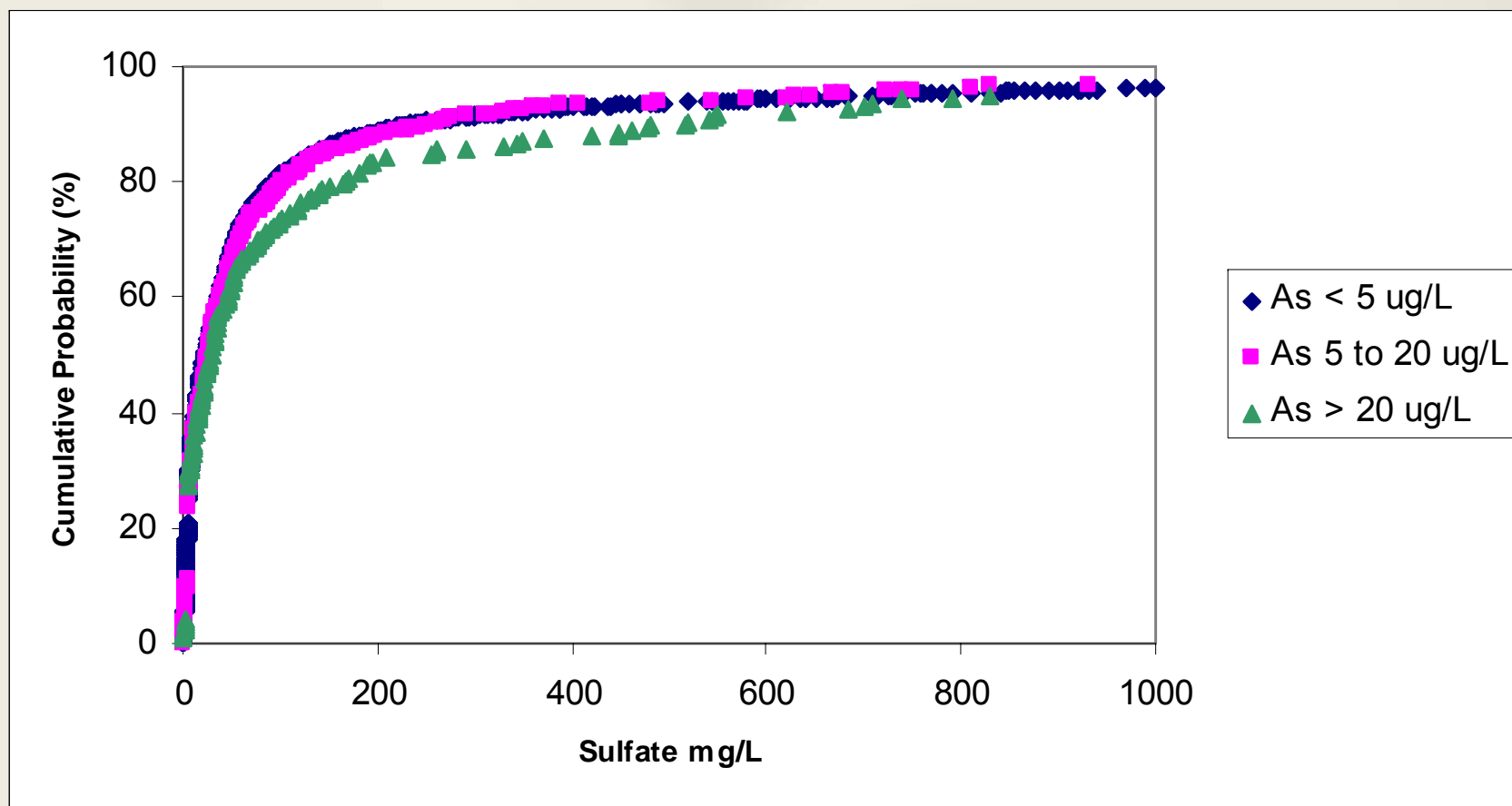
Cumulative Probability Distribution of Phosphate by Binned Arsenic Concentration



Cumulative Probability Distribution of Silica by Binned Arsenic Concentration



Cumulative Probability Distribution of Sulfate by Binned Arsenic Concentration



Comparison of NSF Challenge Water to Co-occurrence Data

Parameter	Unit	NSF Water	Moderate As Water		
			50 th	75 th	90 th
Sodium	mg/L	74	43	120	330
Calcium	mg/L	40	55	106	174
Magnesium	mg/L	13	12	26	50
Alkalinity	mg/L –CaCO ₃	150	246	344	466
Chloride	mg/L	71	31	84	273
Fluoride	mg/L	1	0.3	0.7	1.6
Sulfate	mg/L	50	27	79	260
Nitrate	mg/L -N	2	1	5.3	14.8
Phosphate	mg/L -P	0.12	0.13	0.28	0.55
Silica	mg/L – SiO ₂	20	14	21	32
TDS	mg/L	307	374	572	1090



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Summary

- Co-occurrence database developed from retrospective analysis of USGS data
- Quality of arsenic bearing water differs from non-arsenic bearing waters
- NSF challenge water is roughly representative of a 50th percentile co-occurring water
 - Media may see more aggressive conditions at many locations

Acknowledgements

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Most of the project was performed while employed by McGuire Environmental Consultants



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